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## The Impact of a ceramic wear liner on the separation efficiency of a particular cyclone dust collector

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### Abstract

Cyclone separators are widely used in the gas solid separation processes. Their dimensions and configurations have a great influence on their performance and they have been widely studied in literature. In this research, the impacts of using a ceramic wear liner inside the wall of a special dust collector cyclone, installed in the Golgohar mining and industrial company in Iran, is investigated. In this research some numerical calculations and software analysis, based on the CFD, have been carried out and the results have been compared with the results of the practical tests and recorded data. This comparison shows the conformity of the results of the practical tests and the calculated results. In this research, the flow is a two-phase, gas-solid, type and the collision of the solid materials, which are mainly iron material with 200~700 micron dimensions, with the cyclone wall will increase the erosion. Therefore, to reduce the erosion a special ceramic wear liner is used as a protective layer for cyclone wall. Adding this protective layer has changed the geometry of the cyclone wall from different aspects; so the impacts of this type of liner on the performance and the separation efficiency of the dust collector cyclone should be investigated. The dilute two phase flow inside a cyclone is simulated using an Euler-Lagrange hybrid method. The gas phase is governed by the Navier-Stokes equations. This investigation can be a starting point for more research that can be result in producing more appropriate and efficient cyclones. For more accuracy, the comparison have been done for different speed of flow and the results show that this liner has a negative impact on the dust separation efficiency in this cyclone.

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## 1. Introduction

Cyclone separators are widely used in the gas solid separation processes. Their dimensions and configurations have a great influence on their performance and they have been widely studied in literature. In this research, the impacts of using a ceramic wear liner inside the wall of a special dust collector cyclone, installed in the Golgohar mining and industrial company in Iran, is investigated. A strong rotation of gas is induced in the cyclone and the centrifugal forces are exerted on the particles, separating them from the gas flow toward the cyclone wall [1], [2]. In general, the flow field inside a cyclone is characterized with strong swirling vortex, and it is critical to the performance of cyclone separator. It's obvious that, there are many factors that have a big influence on the flow field, such as the geometry of cyclone and the operating condition [3], [4]. Fortunately, these two factors has been investigated by many researchers using both experiment and simulation [5].

## 2. Analysis and Modeling

The dilute two phase flow inside a cyclone is simulated using an Euler-Lagrange hybrid method. The gas phase is governed by the Navier-Stokes equations:

$$\frac{\partial \rho}{\partial t} + \text{div}(\rho u) = 0 \quad (1)$$

$$\frac{\partial(\rho u)}{\partial t} + \text{div}(\rho u u) = -\nabla P - \text{div}(\tau) + \rho g \quad (2)$$

Where  $\rho$  is gas density,  $u$  is gas velocity vector,  $p$  is pressure and  $\tau$  is the stress. The particles are tracked by Newton's law of motion:

$$\frac{dV_p}{dt} = F_D(u - V_p) + g \left( \frac{\rho_p - \rho}{\rho_p} \right) + F \quad (3)$$

Where  $V_p$  is particle velocity,  $\rho$  is particle density,  $F$  is an additional acceleration force.  $F_D$  is drag coefficient and is calculated by:

$$F_D = \frac{18\mu}{\rho_p d_p^2} \frac{C_D Re_p}{24} \quad (4)$$

Where  $C_D$  is calculated by an empirical equation [6].  $\mu$  is the gas viscosity,  $d_p$  is particle diameter and  $Re_p$  is particle Reynolds number given by:

$$Re_p = \frac{\rho |u - V_p| d_p}{\mu} \quad (5)$$

In this study, we investigate the effect of using a particular type of anti-wear ceramic coating liners on efficiency of a particular type of cyclone separating solid steel particles from air, as it is shown in figure 1. These liners are in form of rectangular cube of dimensions 0.02×0.3×0.4m, the simulation of this particular type of cyclone is carried out by Ansys Fluent software. There is a comparison between the two models in software analysis based on CFD method as shown in figure 2, the model entitled (A) has no ceramic liner and the other model entitled (B) has a particular anti-wear ceramic liner. To validate the numerical results, measurements and experimental calculations of dust separation efficiency in the cyclone equipped by ceramic liner (model (B)) are done in place. This equipment is used in iron ore industry and is emplaced in refining factory of Golgohar-e-Sirjan mining and industrial company in Iran. Numerical and experimental results comparison accomplished in this study, shows good agreement between numerical and experimental results. Inner net volume of this cyclone is about 80 m<sup>3</sup> and about 2200000 mesh cells are used in its tetrahedral meshing and to survey the analysis results from this point of view that numerical results are independent of mesh cell dimensions, this analysis results is also compared with the results from about 1700000 and 3400000 cells analysis which showed good agreement. The separation efficiency analysis and comparison in

these two models is carried out at two entering cyclone conventional flow velocities of 20 m/s and 30 m/s. According to experimental measurements at each speed, dust particles mass rate entering the cyclone is measured and applied in releasing from cyclone input. In situ experimental measurement method is based on the arrangement equipment is installed before and after the cyclone, and by measuring dust mass rate separated by the electrostatic precipitator emplaced after the cyclone and separate the escaped dust from air in output suction above the cyclone and by knowing the ESP (Electrostatic precipitator) tool separation efficiency and also by measuring the discharging solid phase mass rate from the cyclone underflow, one can easily measure the solid phase mass rate at cyclone input and three outputs. To change the flow velocity a flow regulation damper is used at the end of flow path of cyclone set and ESP, right before the flow sucker fan. Except the input placed at the center of cyclone and the main suction output placed above the cyclone and also dust collecting output or the cyclone underflow placed beneath the cyclone, there is as well an output at the center of the cyclone facing exactly the cyclone entrance that led to the next cyclone input, as it and its grid is obvious in figure 2. The purpose of modeling the third output has been enhancing the simulation accuracy. Another point considered to achieve more accuracy is that for applying boundary conditions in this analysis entering pressure is considered as cyclone main input pressure and some parameters are exactly applied in, such as hydraulic diameter, and turbulent intensity, and three other outputs are used to apply outgoing velocity with input velocity boundary condition but negative velocity direction. The exerted model is selected due to rotational flow and high accuracy in inner air flow analysis and also precision near RNG-K-epsilon wall with spin factor of 0.5. The dimensionless parameter  $S=z/H$  presented in table 1, introduce the location of sectional plates and the lines placed on these plates.  $H$  parameter is 12 meters length and present the total height of cyclone and  $z$  is the height location on  $Z$  axis that starts from the cyclone underflow. Static pressure comparing contours and axial velocity and tangential velocity on these sectional plates and also related comparing diagrams plotted on the lines located on these plates on  $x$  axis, are illustrated in figures after figure 3. As it is distinct in figure 1 undoubtedly geometrical parameters such as rectangular cubic dimensions of the liner that lead to a multi side section cyclone and also prismatic void with triangular section that is installed in the inner body and conical part of cyclone because of the cyclone arrangement, affect the flow and this study evaluate this effect. So the effect of two aforementioned geometric factors on cyclone separation efficiency is investigated in this research. In some diagrams some parts are discrete because the selected sectional plate collides the metal edge of inner cylinder wall especially at  $S3$  location and because of this in these points due to absence of fluid we encounter disconnection in the diagram.

Table 1. The position of different plotting sections<sup>a</sup>.

Section	$z/H$
$S1$	0.33
$S2$	0.50
$S3$	0.66

(a) “ $z$ ” is measured from the bottom of cyclone and  $H=12$  m is total height of the cyclone.

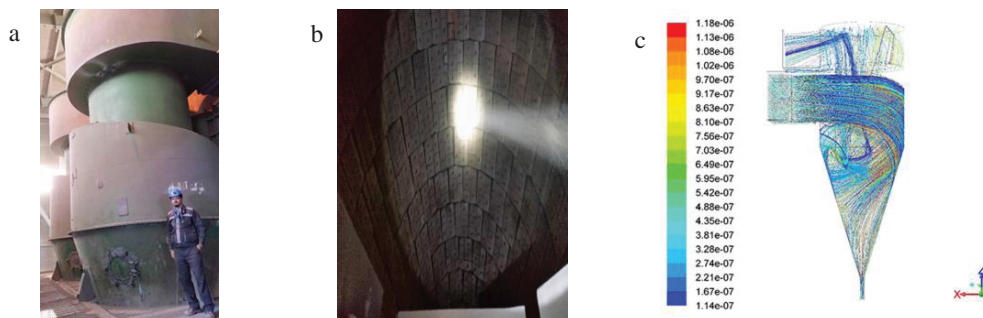


Fig. 1. (a) Exterior view of the cyclone; (b) Interior view of the cyclone; (c) Separation of particles (kg).

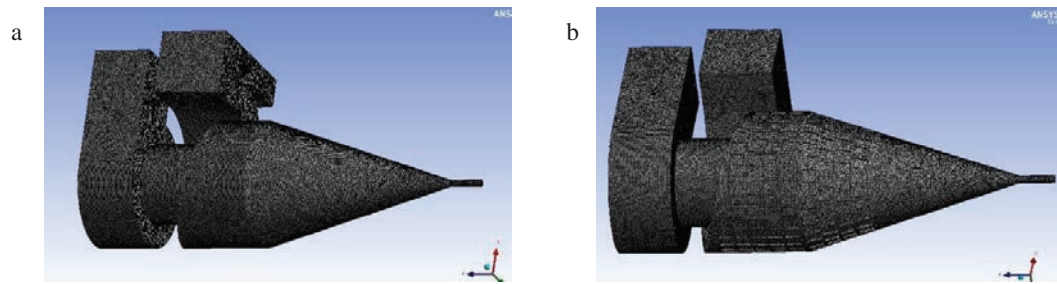


Fig 2. (a) Grid of model "A"; (b) Grid of model "B".

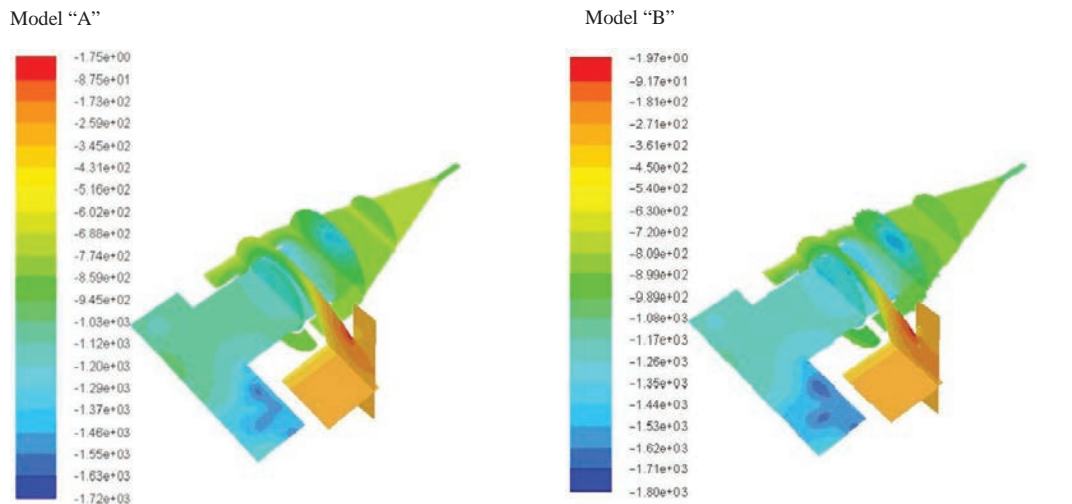


Fig 3. The static pressure contour plots ( $N/(m^2)$ ) for the different sections with inlet velocity=20m/s.

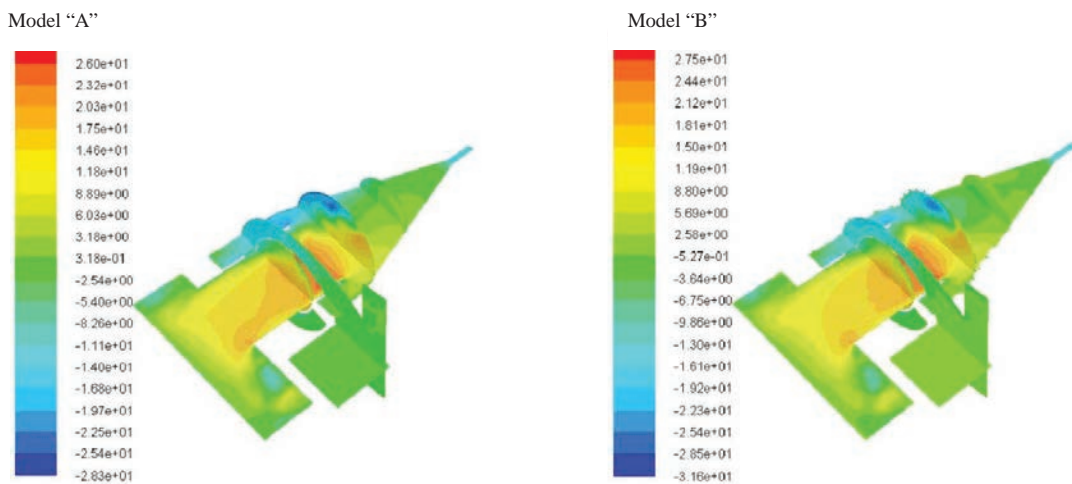


Fig 4. The axial velocity contour plots (m/s) for the different sections with inlet velocity=20m/s.

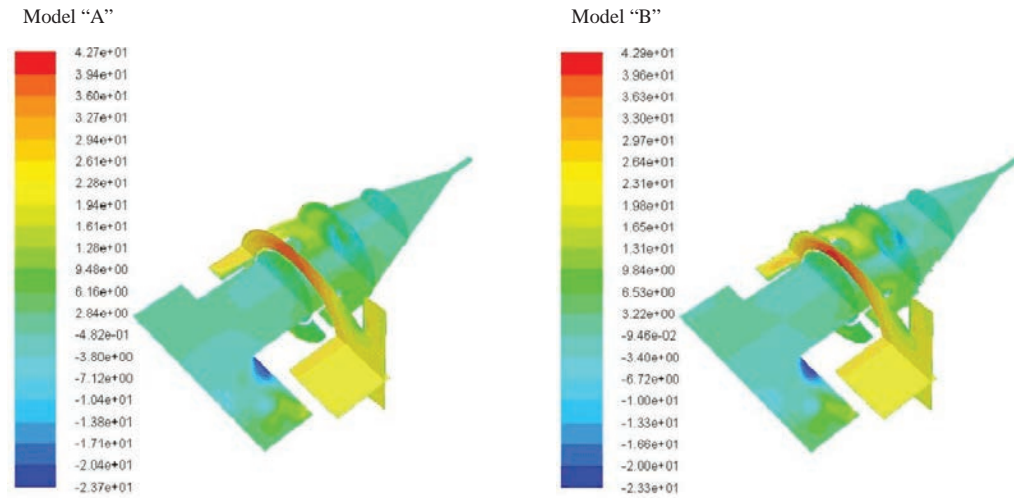


Fig 5. The tangential velocity contour plots (m/s) for the different sections with inlet velocity=20m/s.

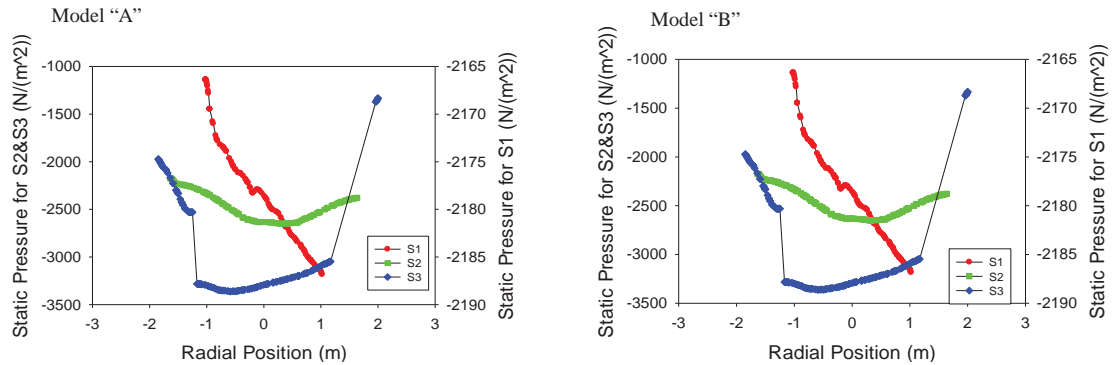


Fig 6. The radial profiles for the static pressure at different sections for the two cyclones with inlet velocity=30m/s.

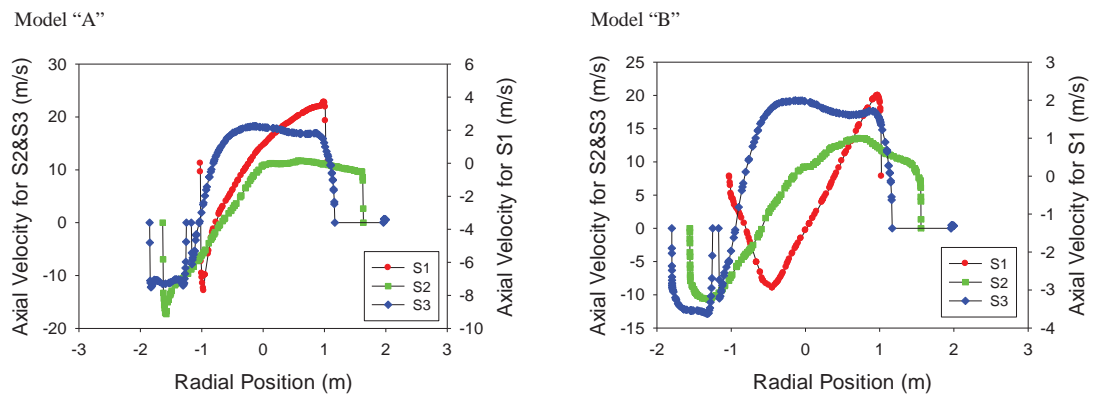


Fig 7. The radial profiles for the axial velocity at different sections for the two cyclones with inlet velocity=20m/s.

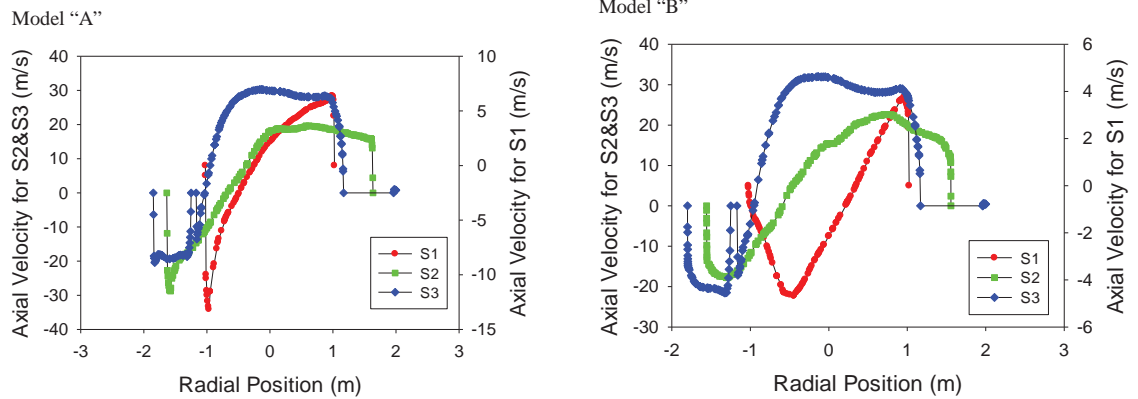


Fig 8. The radial profiles for the axial velocity at different sections for the two cyclones with inlet velocity=30m/s.

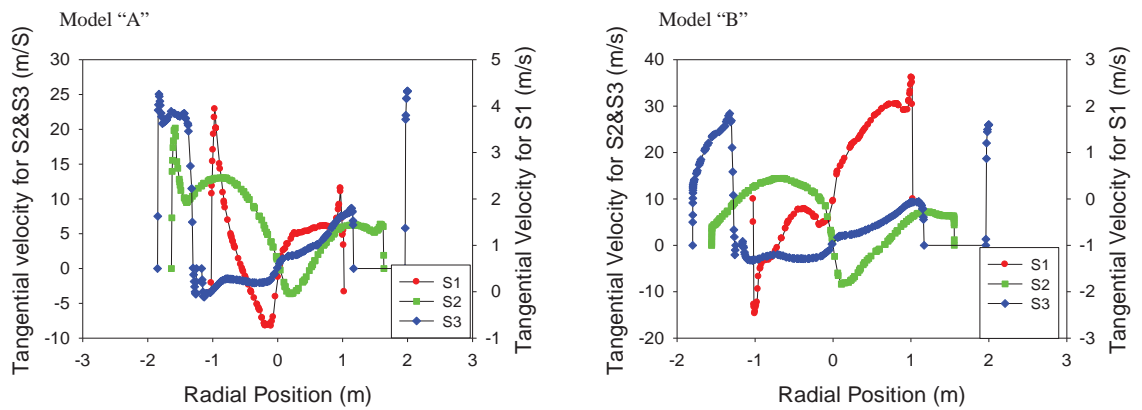


Fig 9. The radial profiles for the tangential velocity at different sections for the two cyclones with inlet velocity=20m/s.

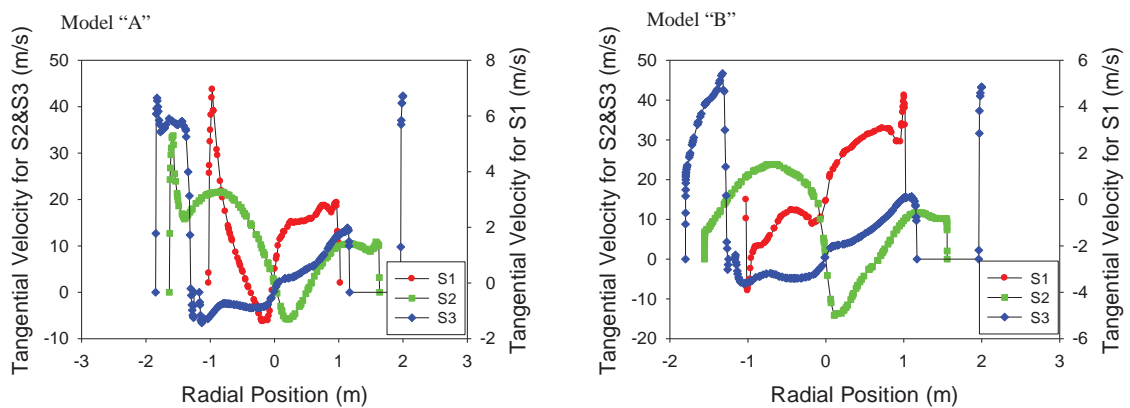


Fig 10. The radial profiles for the tangential velocity at different sections for the two cyclones with inlet velocity=30m/s.



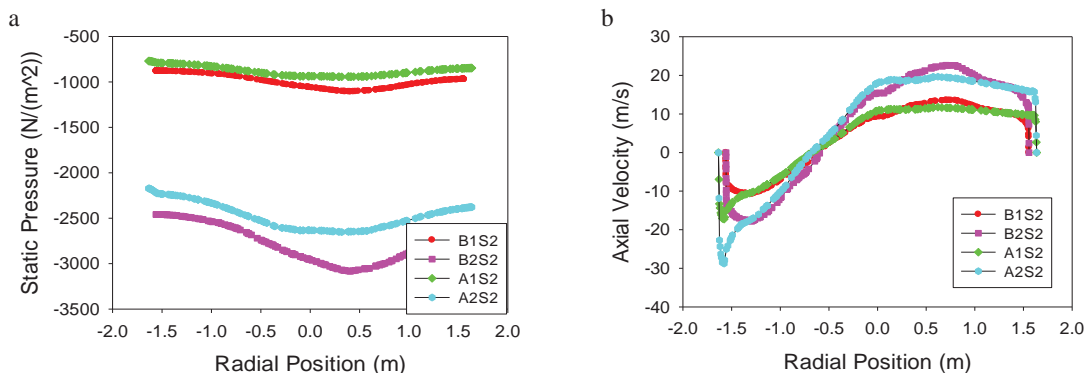


Fig 11. (a) Comparison of static pressure on the section of S2; (b) Comparison of axial velocity on the section of S2.

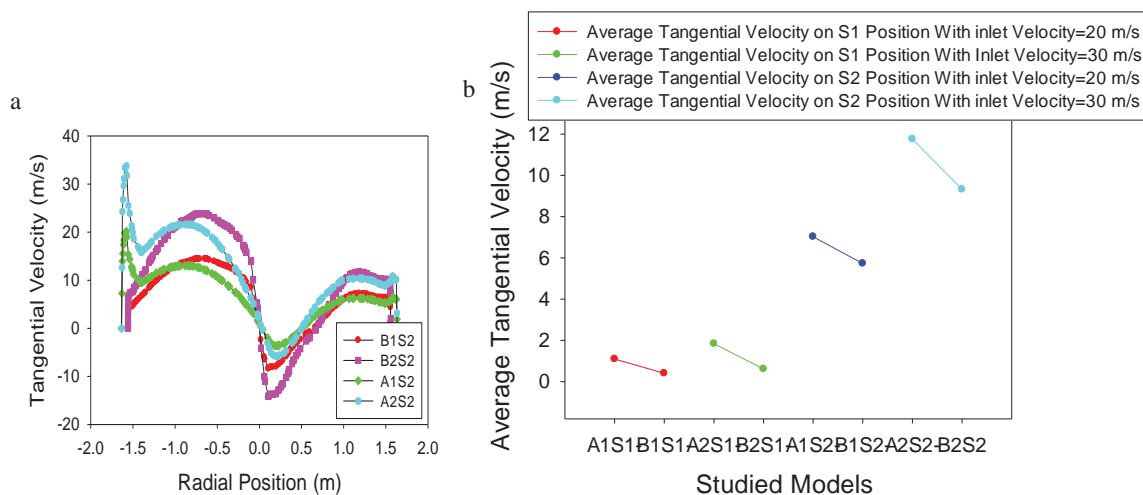


Fig 12. (a) Comparison of the tangential velocity for the two models of cyclones with different inlet velocity (20 & 30 m/s) on the section of S2; (b) Comparison of Average tangential velocity between models of (A) and (B) on different sections (S1 & S2) and different inlet velocity.

Table 2. Separation efficiency of the cyclone dust collector

Inlet Velocity (m/s)	Numerical efficiency for the Model of (A) <sup>a</sup>	Numerical efficiency for the Model of (B) <sup>b</sup>	Experimental efficiency for the Model of (B) <sup>b</sup>
20	0.87	0.82	0.85
30	0.93	0.86	0.89

(a) Model of (A) is the cyclone without ceramic liner.

(b) Model of (B) is the cyclone that contain ceramic.

### 3. Experimentally Method

The electrostatic precipitator is located after the cyclone and the damper regulator that located after the electrostatic precipitator, regulated the cyclone inlet velocity to 20 and 30 meters per second. Then while the equipment was in normally worked and assuming the efficiency of 80% for the electrostatic precipitator and by assuming the same diameter for the particles, mass passes from bottom conveyors that located under the equipments (cyclone and electrostatic precipitator) for one day was measured. Experimental efficiency of the cyclone was

calculated by divided the bottom output mass of the cyclone into the sum of the bottom output mass of the cyclone and the bottom output mass of the electrostatic precipitator. This result is for the model entitled (B).

#### 4. Results and Discussion

Comparison between general comparative diagrams including static pressure and tangential velocity and axial velocity is observable in figures 11&12. As we know tangential velocity in the cyclone, exerts more eccentricity force on solid particles, therefore there is more particle separation at higher tangential velocities. Figure 12 (b) shows average tangential velocities general comparison in different crossover plates of cyclone. In the diagram related to figure 12 (b) mean tangential velocity in the cyclone with no ceramics (A) model is higher than the cyclone with ceramics (B) model, i.e. the separation efficiency in cyclone (A) is higher than cyclone (B). In the following by performing analysis on the solid phase, its sample is shown in figure 1 (c), and by calculation the proportion of outgoing particles from cyclone underflow to entering particles, the cyclones separation efficiency is calculated and the results can be seen in table 2. To validate the results achieved from analyzing the cyclones having ceramic liner, considering the aforementioned methods experimental tests at different velocities were done and general results of separation efficiency from numerical and experimental methods which are inserted in table 2, showed good agreement between numerical and experimental results.

#### 5. Conclusions

Considering the mentioned explanations and according to the diagram in figure 12 (b) and the comparison between numerical results inserted in table 2, the negative effect of this coating ceramic liner on separation efficiency is absolutely clear. As a suggestion for more research in future one can work on optimization of geometric shape and other design factors of this type of liner. For example if liners are curved and ending coating edges are considered in a way that no voids will be left after installation, one can improve the cyclone efficiency as well prevent abrasive solid particles and dust enter the expensive equipment like ESP and suction fan emplaced after the cyclone to decrease the high costs of these tools maintenance. Also electrical energy usage of ESP equipment will decrease due to decrease in entering load and escaping dust from all these equipment to environment decreases too, so environmental contamination is mitigated. In addition, the load of outgoing particles from cyclone underflow that is known as a product has increased and will increment the production of iron concentrate.

#### Acknowledgement

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#### Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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